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ELECTRIC RESISTANCE WELDING IN THE AIRCRAFT INDUSTRIES

By ROBERT SEGNA

IT is surprising to learn what a large number of welded parts are included in the construction of the newest airplanes. Thousands of individual welds are spread throughout the structure, and all are of the utmost importance to the safe and required performance of the ships. Electric resistance welding is a primary factor in the fabrication of numerous structures on the airplane, and because much of the acknowledgment for the remarkable advancements attained in this field can be accredited to the pioneering efforts of the aircraft manufacturers, we shall limit ourselves to a discussion of its progress and present status in the aircraft industry.

Although something about the simplicity, rigidity, and high strength of welded joints was known long before the first airplane flew, the values obtained from this type of construction were not utilized in aircraft manufacture until fairly recent developments and refinements opened up possibilities for innumerable applications along this line. Because the investment in welding equipment at the factories was negligible and the flexibility for the numerous complicated fittings in air craft parts required intricate and expensive machinery, these applications were very limited until more practical methods embracing new materials, higher speeds, stronger welds, and regulated timing and current flow were developed.

Some four or five years ago, the aircraft manufacturers realized the possibilities of this process, but the difficulties that prevented the practical production of electric welding were manifold. It was an entirely new field, and no manufacturer knew what was essential either in the way of equipment or technique. Because the equipment firms did not have this information themselves, the aircraft corporations undertook the problem alone, endeavoring to design and construct their own equipment. The outcome of such futile attempts only produced machinery that lacked sufficient electrical capacity, proper timing, and flexibility for adjustments on different materials and gages. Secrecy among the respective concerns only added to the tension and if all their information had been compiled earlier, the advancement in this process would be more firmly established today.

The situation finally cleared up in the last three years when the Materials Division of the Army Air Corps conducted experiments and tests on the process and disseminated all the information from the various manufacturers. At the present time it is possible to install efficient machinery and to raise technique and production standards to the proper level necessary for the use of resistance welding.

Resistance welding is divided into two parts: spot welds and flash welds. They are both used in aeronautical work, although spot welding has proven the most practical as well as popular among the organizations. In spot welding, the industry has made its most remarkable developments, and the reason for these achievements must embody all the economical fundamentals to the trade. It is undoubtedly the most reasonable method of joining together two sheets of metal that might be used for fabrication, tanks, or detailed parts. In certain applications such as interior fittings of commercial passenger airplanes smooth surfaces on the interiors present a distinct aesthetic value. By eliminating projecting rivet heads on the external surface of the ship, the skin-friction and consequent drag conditions are reduced. Stress and stress-resisting analysis of this method of fabrication also illustrates that it is the strongest process. Again, on certain types of materials such as corrosion-resistant steels, spot welding is the only practical method of joining the sheets regardless of cost.

As far as riveting is concerned, it is inefficient from a joint strength standpoint, and costly because of the labor and tooling involved. It must be remembered that in order to rivet, a hole must be drilled, which reduces the strength of the joint by removal of material. Spot welding does not remove any material, and the union of the sheet is made without the addition of flux or extraneous stock. As an added proof of its advantages, we need merely to point to the automobile and railroad industries which have both adopted this process for certain assembly functions.

If we were to inspect the modern aircraft factory, we would observe that this process of resistance welding has now been adopted for the construction of the airplanes,

the engines, and a large amount of the accessories. Sleek, streamlined airplanes with all metal covering could never be assembled or fabricated if welding had not been introduced and developed in this field.

Possibly, the development of new electrical and mechanical devices for controlling the timing period of current passage has improved the condition of spot welding more than any other factor. Such welds are now replacing rivets in all parts of the airplane inasmuch as they have definite spacing and are designed for sheer stress only. We might describe a spot weld as the joining of two pieces of material by placing them between two electrodes under pressure and utilizing the heating effect of a heavy current for a definite period of time. The intimate contact causes a small slug or spot to be fused between the sheets at the point of contact so that they are joined together as a single sheet at the spot.

It is especially the electronic-tube timing control that has made spot welding of aluminum alloys and other metals a practical manufacturing process. This automatic control of the time and pressure of the current has brought about a high degree of uniformity in strength and ductility of the fused spots. General Electric Thyrotron panel controls containing several electronic-tube timing controls, consist of two mercury pool rectifying tubes ignited by a radio current. The time of current flow is adjusted by a dial on the front of the cabinet so that the actual time that the current runs is less than $1/20$ of a second. The use of such short periods makes it theoretically possible to weld 1,800 spots per minute although a much smaller number is more practical in actual use. The small area of heat application is so fitted that the original physical properties are retained and warping tendencies are reduced by the process.

Included in the equipment besides the Thyrotron control panel is the sequence panel controlling the sequence of operation. This cabinet also includes an auto-transformer to decrease the voltage thereby precluding any possibility of a dangerous electrical shock to the operator. Alternating current supplies practically all the commercial spot welding in the United States. This current is a distinct advantage because it can be interrupted at or near the zero point of a wave by some synchronous device so that the electrical energy can then be converted by means of the transformers into high amperages at low voltage values. This is done to eliminate the possibility of a shock to the operator.

The welder (like the machine illustrated in figure 1) looks like a huge jig saw with two electrodes at the end where the saw blade would normally be found. These electrodes are either in the form of straight copper electrodes or circular electrodes that roll along the seam forming a so-called seam weld that may run a continuous weld along the joint or work as a series of spots. When the operator pushes the foot button, the air pressure is applied to the electrodes before the current

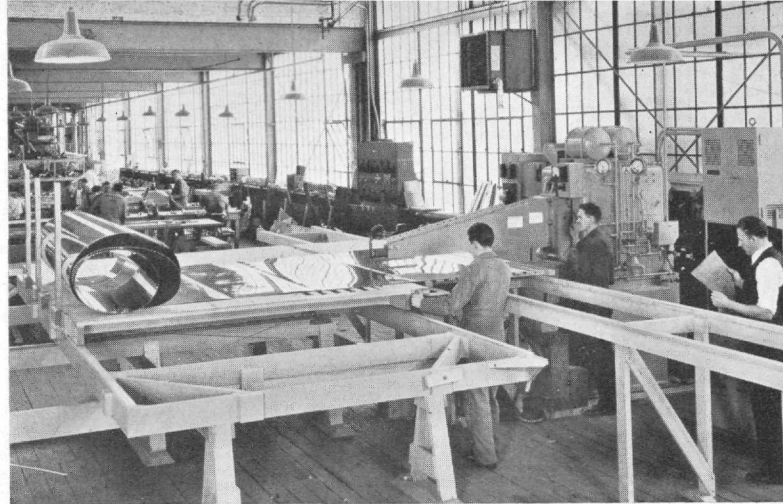


Figure 1 showing a welder which looks like a huge jigsaw with two electrodes at the end where the saw would normally be found.

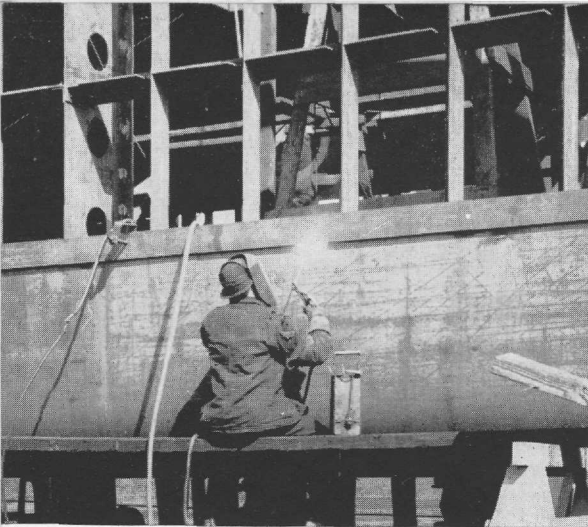
flows and is released immediately afterwards. The amperage to weld heavy gages of aluminum is in the neighborhood of 30,000 amps., although much smaller amperages are used on the lighter sizes, and for this reason the welding arms and electrodes become tremendously hot and must be water cooled to prevent their melting. An instrument panel mounted on the welder contains an air pressure dial, a consistency indicator which rings a bell when a weld is finished, and an ammeter which deflects when trouble is experienced with the Thyrotron control. This latter feature is to safeguard the delicate and expensive radio tubes.

Resistance welding equipment uses many types of construction similar to those used in other machine tool practice. They may follow quite closely planer, milling machine, screw machine, punch press, lathe, or other machine tool designs having a resistance welding station where the usual tools would be used. The vast field of automatic machines includes too many different designs to be fully covered herein. The several classifications, however, are discussed and a description of a few typical machines is included.

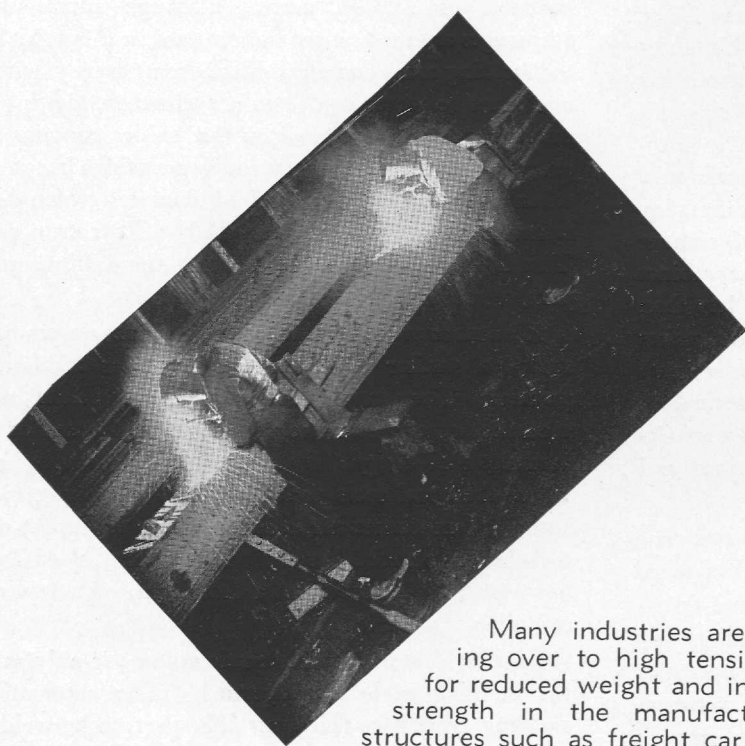
Spot welders are usually made automatic only as far as the welding cycle is concerned. The automatic spot welding cycle is as follows: The parts to be welded are placed in the welding machine and the electrode points are brought in contact with the parts to be welded and pressure applied. After pressure has been established, power is applied to the work through the electrodes and simultaneously the pressure which is arranged to give instantaneous follow-up presses the parts together. The power is then shut off, the pressure relieved and the part just welded removed from the machine. This cycle is fully automatic and must be adhered to if satisfactory welding is to be expected. The sequence is obtained in many ways through the use of cams, air or hydraulic systems or straight mechanical means, but whatever method is used the above sequence must be produced.

There are a great many different types of automatic or semi-automatic seam welders which have been built

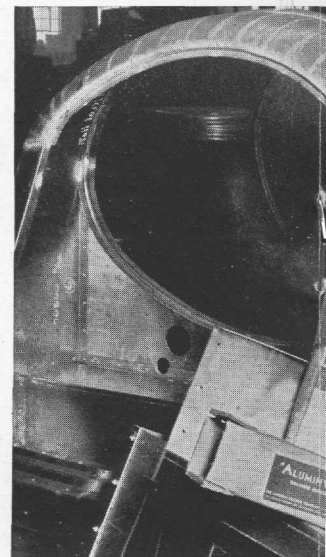
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Arc welded construction cuts steel tonnage in buildings, bridges and ships 10% to 20%. By making possible reduced dead weight in the construction of this freighter, welding increased payload capacity 300 tons.



Many industries are swinging over to high tensile steel for reduced weight and increased strength in the manufacture of structures such as freight car sills as shown above.



Many machine parts, forgings or casting, are now being joined in sections together with arc welding is used in the fabricating equipment.



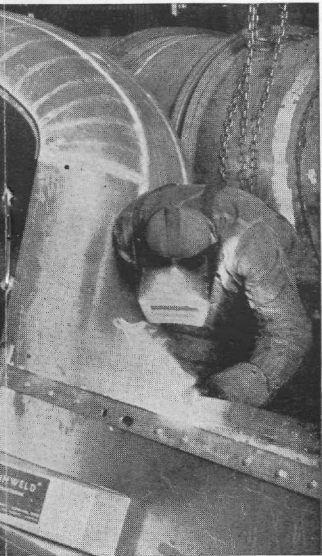
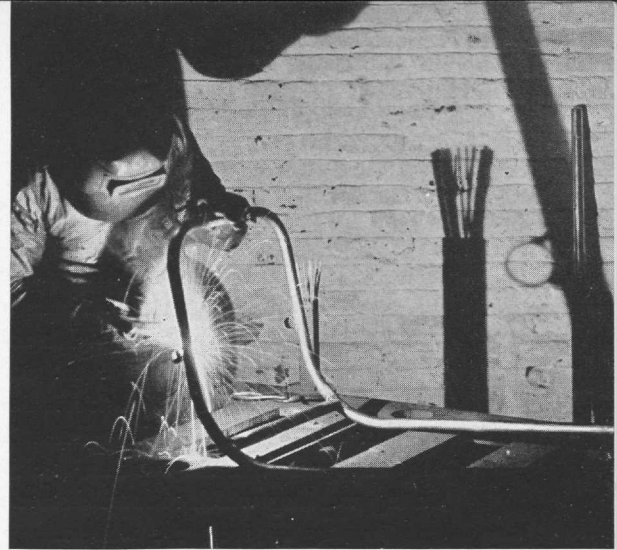
Parts of machines and machinery are being hardened by the electric arc welding process. This welder is working on a bucket in the construction of a canal.



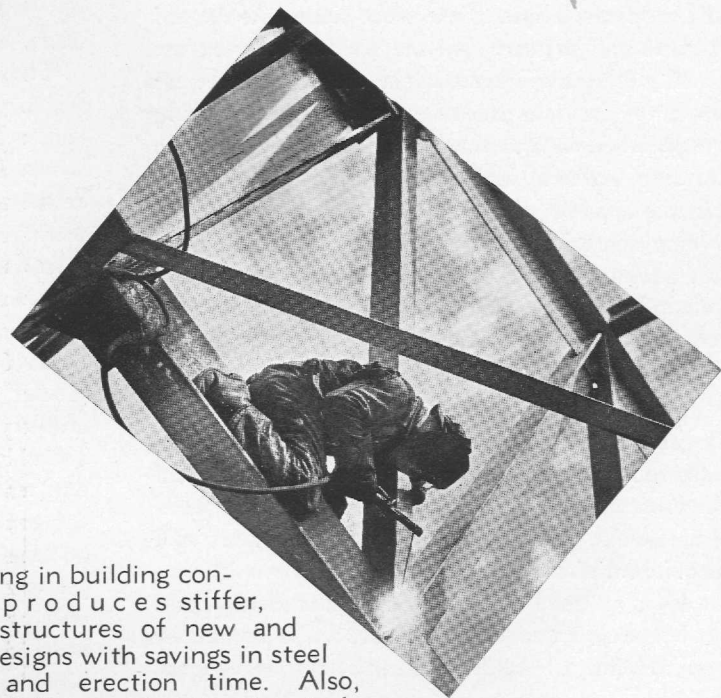
In mills, mines and factories throughout the world, electric arc welding serves as a handy maintenance tool, saving thousands of dollars yearly in replacement costs of broken and worn products, and in building special manufacturing equipment.

Cuts used on these pages furnished by Lincoln

The man behind the mask welds a magic wand of steel fusing metal to metal for lower costs and improved quality. Here, thin gauge steel tubing is converted into strong, rigid frames for airplane chairs.



formerly built by riveting
ing built by fusing metal
the electric arc. Here,
the manufacture of venti-



Arc welding in building construction produces stiffer, stronger structures of new and unusual designs with savings in steel tonnage and erection time. Also, welded building construction is noiseless.



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An authority says that 75% to 85% of all oil and gas pipe lines built today are of arc welded construction. Here, a welder is completing a "bell-hole" weld.

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In Electric Company.

and placed in successful operation. Sheet metal parts which may be formed by rolling may have a seam welding station attached and turn out continuous production in the form of light weight closed structural shapes of several different sections. The welds are made in a series with a pair wheels, one above the other, and the table of this machine is actuated back and forth by a hydraulic cylinder and an oil pressure pump. The table is made deep enough so that the work may be flooded with water during welding which reduces distortion to a minimum and thoroughly cools the wheels.

The sequence of operation of this machine is as follows: The plates to be welded are clamped to the copper plate which already is flooded with water. The machine is started by a push button. The four wheels, each equipped with a separate air cylinder, come down and apply the welding pressure. The hydraulic valve is opened and the table starts to move. At the same time, a limit switch closes the contactor applying the welding current. The table travels at a predetermined speed and welds the length of the work piece. As the end is reached, the oil pressure and the welding current are turned off. The air is reversed in the wheel pressure cylinders and the wheels are raised. The indexing motor is switched in and the wheels index over to the next welding position, and the welding cycle is repeated in the opposite direction. On the completion of five welding operations or twenty seams, the wheel head and table automatically return to their original position. The work piece is taken from the machine and another is loaded and the welder is ready for its next sequence of operations.

The specifications for the inspection of resistance welding consists of indirect tests on equipment and samples performed by the equipment before, during, and after the process is run. These samples must meet specified tensile-test requirements. X-ray inspection of spot welds is quite satisfactory.

Flash welds are used on simple butt joints of tubes and forgings but the application of this process is limited by the large amount of equipment necessary for special designs.

The material to be welded determines the specific weld that must be applied. Chrome-molybdenum steel is used on stress structures because of its high tensile strength ranging between 160,000 and 200,000 lbs. per square inch. It can be readily welded with reliable technique by the spot welder, but the permanent contraction of the steel near the weld after it has cooled may cause the metal to crack or weaken so that it must be heat treated to relieve residual stresses. Engine fittings, landing gears, center sections, and highly stressed sections of the fuselage and surfaces employ the use of this steel. Jigs are used to support the members in the furnace from distortion during the heat treatment. This steel has a strong tendency to corrode which is prevented by sand blasts and cadmium plating

the surface after the weld has been performed.

Cold rolled stainless steel is replacing the Chrome-molybdenum steel in many places, chiefly because it does not corrode. At first the tensile strength of this steel was only 90,000 lbs. per square inch, but recently high tensile steel of 185,000 lbs. per square inch has been developed by the steel companies. Unlike the other steel, sudden chilling from a high temperature anneals the material and shot welding proves an excellent method of fabrication. This steel has proven eminently satisfactory on the large four motored ships where strong structures are necessary.

The successful application of welding for construction of interchangeable parts, assembled in close alignment, is made possible by jigs and fixtures to hold the parts during the welding process. The design of jigs requires ingenuity and knowledge of the laws of expansion and contraction of metal. Cracks may be formed by warping or contraction. The parts are cut to the proper size, fitted in the respective places on the jigs that are built strong and massive to hold their true shape, after which they are joined.

The U. S. Army Air Corps and The Bureau of Aeronautics have established certain specification tests for welders in the aircraft industry. Every operator is required to have a certificate obtained from the government through a practical examination. Diligent work on the part of the companies, workmen and inspectors have all contributed to keep this necessary and important phase of aircraft manufacturing detail on the admirable plane that it is today.

As far as the future is concerned, any attempt to predict the course of resistance welding in the aircraft industry is futile. It is thoroughly established for the assembly of unstressed parts and secondary structure, but when corrosion-resistant steels are used generally for primary structure, resistance welding will inevitably become a major production method. In other words, the possibilities for electric resistance welding are limited only by the number of uses that are required of it. The more the engineers develop, the more immense it will become, eventually resulting as a major production process.

The author wishes to thank the Consolidated Aircraft Corporation and "The Welding Journal" for their help in getting material. The illustration was furnished by the Boeing Aircraft Company.
